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# Errors in Shaping by a Planetary Mechanism

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**Abstract**—The proposed planetary reaming method permits discontinuous turning in which the cutting edge moves relative to the cutting surfaces. As a result, individual sections of the cutting zone move successfully in and out of the machining zone. Discontinuous turning is free of the deficiencies of continuous turning.

*Keywords:* discontinuous turning, planetary machining, shape error, surface roughness
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In continuous cutting, when the cutting surface is in contact with the moving chip and the rear surface of the part throughout the machining process, high temperatures appear in the cutting zone and are transmitted to the cutter by the chip and the machined part.

The supply of working fluid to the cutter is hindered because the chip and the machined surface interact continuously with the front and rear cutter surfaces under considerable pressure. As a result, the working fluid mainly cools the chip and the machined part. In combination with the high temperature, the practically dry friction at contact of the chip and the machined surface with the cutter results in intense tool wear and reduces the precision of the machined surface.

These processes are associated with distortion of the part produced, which deviates from a regular circle (Fig. 1). For design purposes, we need to estimate the resulting error Δ. To that end, we use the geometric theory of shaping.

The basic shaping equation takes the form [1]:

$$\overline{r}_{\mathrm{m}}(\varphi, z, \theta) = A_{\mathrm{tr}}(\varphi, z, \theta)\overline{r}_u,$$

where $\overline{r}_{\mathrm{m}}$ is the radius vector of a point on the machined surface; $\overline{r}_u$ is the model of the cutter; $A_{\mathrm{tr}}(\varphi, z, \theta)$ is the transformation matrix of the shaping system, which may be written as the product of matrices.

In machining by a planetary mechanism, the transformation matrix takes the form [2–14]

$$A_{\mathrm{tr}} = A^3(z)A^6(\varphi)A^2(R-r)A^6(-\theta),$$

where $A^3(z)$ is the displacement matrix of the workpiece along the $z$ axis

$$A^3(z) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & z \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

$A^6(\varphi)$ is the rotation matrix of the satellite in the planetary mechanism with the cutter block at the shaft

$$A^6(\varphi) = \begin{bmatrix} \cos(\varphi) & -\sin(\varphi) & 0 & 0 \\ \sin(\varphi) & \cos(\varphi) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

$A^2(R-r)$ is the matrix determining the distance between the axis of the workpiece and the axis of the satellite in the planetary mechanism with the cutter block at the shaft

$$A^2(R-r) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & R-r \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

and $A^6(-\theta)$ is the rotation matrix of the cutter block

$$A^6(-\theta) = \begin{bmatrix} \cos(-\theta) & -\sin(-\theta) & 0 & 0 \\ \sin(-\theta) & \cos(-\theta) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$